THURSDAY, JANUARY 17, 1901.

MODERN THERMODYNAMICS.

An Outline of the Theory of Thermodynamics. By Edgar Buckingham, Ph.D. (Leipzig). Pp. xi + 205. (New York: The Macmillan Company. London: Macmillan and Co., Ltd., 1900.)

THE study of thermodynamics is customarily approached, in treatises and text-books, from a point of view to a great extent the reverse of that which is adopted in opening up the subject of dynamics. In dynamics, the usual treatment is essentially theoretical, as opposed to experimental. Newton's laws of motion are regarded as axiomatical; the second and third laws are employed to afford quantitative definitions of force and mass respectively, the parallelogram of forces is practically assumed, and all which follows is mere mathematics. It is only quite recently that the possibility of teaching dynamics from a more experimental standpoint has been seriously considered.

In thermodynamics it is usual to go to the other extreme. Temperature is defined in the first place by a common thermometer, calorimetry is treated largely in its experimental aspect, and the first law of thermodynamics thus becomes more closely associated in the reader's mind with Joule's experiments on the "mechanical equivalent of heat" than with its interpretation as affording a definition of "quantity of heat." The ordinary treatment of the mechanical equivalent of heat would, in fact, have an analogue in dynamics if we were to start with the pound weight as unit of force, and to define the constant g as the "kinetical equivalent of force."

Of recent years a great impetus has been given to the study of higher thermodynamics by the development of physical chemistry based on the theories first enunciated by Willard Gibbs. The experimental study of what at first was a purely mathematical investigation plays a part in the history of science closely analogous with the experimental verifications of Maxwell's theory by Hertz's discovery of electromagnetic waves. This new development has, to quote Mr. Buckingham's own words, caused "a considerable gap between the text-books available and the modern memoirs." Mr. Baynes's treatise, so long the favourite English introduction to thermodynamics, does not deal with thermodynamic potentials, yet it is with the study of these functions that modern thermodynamics is primarily occupied. Several subsequent attempts have been made to produce text-books on thermodynamics, but their writers have generally introduced long digressions on extraneous matter while omitting many of the most important features of the theory.

What we have been wanting was, in the first place, an application to thermodynamics of the same deductive methods that have been used in building up other connected theories, such as rational dynamics and hydrodynamics, and, in the second place, an introduction to the study of the thermodynamic potential, the conditions of thermodynamic equilibrium and stability for a generalised system the state of which is defined by any number of variables, and not merely by two of the pressure, volume temperature triad, and, lastly, an exposition of the phase rule. In compiling this book Mr. Buckingham is practically alone in the field, and the result of his efforts will greatly remove the difficulties which most students experience in acquiring a knowledge of thermodynamics.

In Chapter i. (Thermometry) the author defines equality of temperature, and enunciates the axiom of equal temperatures, according to which bodies which are of equal temperature with a third body are themselves of equal temperature. Absolute temperature cannot, of course, be defined until the second law; but in introducing the so-called "absolute gas scale," the author is careful to guard against misleading assumptions. In Chapter ii. (Calorimetry) the various heat-units are discussed, and the advantage of the dynamical unit explained. The next chapter practically defines thermodynamic systems and thermodynamic equilibrium; while in Chapter iv. we have the first law enunciated in the form of the statement that for a cyclic process the integral of $dW+dQ$ is zero. Chapters v. and vi. deal with the problem of thermochemistry and the thermal properties o fluids, so far as they can be deduced from the first law alone. A recapitulation of the first six chapters makes up the seventh.

Chapter viii. deals with the second law of thermodynamics. The author, having previously defined absolute temperature on the ideal gas scale, here expresses the efficiency of an ideal gas engine in terms of the temperatures, so defined, of the source and refrigerator. In his proof, Boyle's and Joule's laws are assumed. We do not altogether like this order of treatment. We should prefer to see the second law treated somewhat earlier and used to furnish a definition of absolute temperature the properties of gases, as affording a measure of temperature, being subsequently deduced from Boyle's and Joule's law combined with the first and second laws. This method would altogether obviate the necessity of introducing the "gas scale of temperature." Still, the author is so careful in pointing out what is assumed and what is proved in his work that his order of treatment cannot raise any serious objections.

General Equations (Chapter ix.) introduce the thermodynamic potentials. The next chapter deals with the theory of the plug experiment for determination of absolute temperature, Lord Kelvin's equation, application of the laws of thermodynamics to the E.M.F. of a galvanic cell, change of state, and change of osmotic pressure with the temperature.

In the next chapter we have a summary of the hypotheses and conditions involved in the criteria of thermodynamic equilibrium, followed, in Chapter xii., by a concise account of applications of these conditions involving the use of the thermodynamic potentials, in which Duhem's "total thermodynamic potential" and Helmholtz's "free energy" find their explanations. The book concludes with an application of the free energy principle to the galvanic cell, and a discussion on the triple point, which latter leads naturally up to the more general theorem embodied in Gibbs's phase rule. The discussion of this theorem is somewhat condensed, the author referring to the original papers for a more detailed investigation; but for the readers of a book such as the present the

brevity of the treatment is probably an advantage. A short bibliography forms a useful appendix.

As implied in the title, the author's object has been to give a general outline of the fundamental theory, and not to enter into detailed discussions of applications. The book thus deals exclusively with the theoretical, as distinct from the experimental, aspect of thermodynamics. It may with advantage be studied in conjunction with any treatise in which the theory of heat is studied from the experimental side, and a clearer understanding of the subject will be obtained than would have been the case had Mr. Buckingham written a larger volume, containing a mixture of theoretical and experimental investigations. In a subject like thermodynamics, the fundamental axioms cannot, as a rule, be verified directly by experiment, and we are compelled to use what Dr. Stoney calls the *a posteriori* method. The evidence in favour of the axioms is mainly derived from comparing the conclusions to which they lead with the results of observation. It is important in the theoretical investigation that no assumption should be made which is not expressly stated, and Mr. Buckingham appears at least to have exercised considerably more vigilance in this respect than any previous writer. We should like to see an outline of the theory of electromagnetism treated on parallel lines. Mr. Buckingham's treatise will be an indispensable addition to the library of every physicist or physical chemist, as well as of every applied mathematician who studies thermodynamics, and the author has done much to place the introductory treatment of the subject on a sound and rational basis.

AN AUTHORITATIVE TEXT-BOOK OF PHYSIOLOGY.

Text-book of Physiology. Edited by E. A. Schäfer. Vol. ii. Pp. xxiv. + 1365. (Edinburgh and London: Young J. Pentland, 1900.)

THIS volume consists of 1258 pages of text, 97 pages of indices (subjects and authors), and is illustrated by 449 woodcuts. There is no preface. The following epitome shows the subjects dealt with, their respective authors, and, in brackets, the length of each article:—"Mechanism of the Circulation of the Blood," by L. Hill (1-168); "Contraction of Cardiac Muscle," by W. H. Gaskell (169-227); "Animal Mechanics" (228-273), "Sense of Taste" (1237-1245), "Smell" (1246-1258), J. B. Haycraft; "Muscular and Nervous Mechanism" of "Respiratory Movements" (274-312), of the "Digestive" (313-337), "Urinary" (338-346) and "Generative Tracts" (347-351), E. H. Starling; "Properties of Striped Muscle" (352-450), J. Burdon Sanderson; "Nerve" (451-560), "Electrical Organs" (561-591), Francis Gotch; "Nerve Cell" (592-615), "Cerebral Cortex" (697-782), E. A. Schäfer; "Sympathetic Nervous System" (616-696), J. N. Langley; "Spinal Cord" (783-883) and "Parts of Brain below Cerebral Cortex" (884-919), "Cutaneous Sensations" (920-1001) and "Muscular Sense" (1002-1025), C. S. Sherrington; "Vision" (1026-1148), W. H. R. Rivers; "Ear" (1149-1205), "Vocal Sounds" (1206-1236), J. G. McKendrick and Albert A. Gray.

Those familiar with the modern development and advances recently made by British physiologists will see at once that the selection of authors is a guarantee of the excellence and accuracy of the subject-matter of the several essays; for they may be regarded as such, each essay containing the results of the observations to which the author has directed his particular attention.

It appears to us that Hill's article on the circulation is an excellent *résumé* of the subject, and the author acknowledges that he is greatly indebted to the perhaps not sufficiently well-known "Lehrbuch der Physiologie des Kreislaufes," by R. Tigerstedt (1893), who has recently become professor of physiology in Helsingfors. There has been incorporated all those recently discovered facts bearing on the action and distribution of vaso-motor nerves, and influence of gravity on the circulations, with which readers of the *Journal of Physiology* are familiar.

Gaskell's paper is a philosophic discussion of the many observations that have been made on the action of cardiac muscle. It is done with a master hand, and by one who has materially advanced our knowledge of the subject. Gaskell explains the beat of the heart, the sequence of its contractions, &c., without bringing in ganglion cells at all; and he sees no more reason to assign special functions to these cells than to any other of the peripheral efferent nerve cells; and we think that he makes good his case.

Starling's articles give a clear and precise account of the subjects with which they deal, but we confess that we think a short chapter on the comparative physiology of some of the subjects would have been most valuable. In discussing the influence of the higher parts of the brain on the respiratory centre, we failed to find noted the researches of Marckwald on the effect of plugging the blood-vessels of certain cerebral areas by injecting coloured fluid paraffin wax. These results point to the importance of the posterior quadrigemina and the nuclei of the sensory part of the fifth cranial nerve as important factors in the discharge of rhythmical respiratory impulses (*Zeit. für Biol.*, vol. xxvi.). The earlier observations of Marckwald are given. We are glad to see a full exposition of the work of Kronecker, Meltzer and others on swallowing of liquids.

The mechanical, thermal and chemical properties of striped muscle are exhaustively treated by Burdon Sanderson, as was to be expected from one who has devoted so much time to the study of the time relations of muscle in action, and who, by the introduction of new methods, has added materially to the apparatus by which time-problems in other tissues may be solved. The same may be said of the admirable article on "Nerve" by Gotch, while his paper on "Electrical Organs" groups up succinctly the chief facts and theories regarding these wonderful organs. As to the nature and activity of these organs, Gotch is led to the view that, as the only excitable structures there present are the nerves and their fine terminations, the organ change is closely related to the production of molecular disturbances in its contained nerves. In any case, he regards the essential primary disturbance constituting the organ shock as nervous.

In the editor's article on the "Nerve Cell" we have, as a basis, a *résumé* of the more recent advances in the minute structure of these organs. The modern "theory of isolated units," often spoken of as the "neurone theory," he regards as by no means conclusively proved. In any